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On-site inspections: the shift from forms to digital capture

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Abstract: The building, construction, and real estate industry is undergoing a major transition with traditional ways of working being replaced by novel three-dimensional modeling technologies. Such transitions take place incrementally as more and more actors see the advantages. While new systems (e.g., building information modeling) have become increasingly diffused in the industry, many practices have been left intact. On-site inspections using the old method of filling out forms for the registration of errors and omissions are eventually replaced by defect management systems, where an app on a mobile device is used to take a photo, note position, and write notes, which are directly sent to the responsible people involved. A case study was conducted in a large residential project under completion by a contractor. Project managers and skilled workers were introduced to a specific app and given the opportunity to try it out. Data were subsequently collected based on a series of qualitative interviews conducted with the on-site personnel. This was analyzed according to the technology acceptance model, a theory of user acceptance of new information technologies. Our contribution is that we compare the technology acceptance of new and existing defect management methods and unearth their relative advantages, while registering how users' perceptions of new technology affect their intention to use as well as their actual continued use of the technology. This work is important for managers planning development of their on-site management tools, enabling them to run their projects more efficiently.

Keywords: on-site inspection, defect management systems, technology acceptance model

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1 Introduction

According to several studies, most building defects originate during production or construction (Josephson and Hammarlund 1999). Much time and effort is spent on inspecting and documenting construction defects in buildings (Nguyen et al. 2015). Furthermore, they are costly – rectifying is assumed to account for up to 15% of the total construction costs (Yue et al. 2019). Inspections may be carried out during construction and during use, as well as during takeover (Nguyen et al. 2015). While prevention would be preferable, it is not always possible or even the most cost-effective (Vaxevanidis and Petropoulos 2008), so there will always be a need for appraisal and correction of defects.

Digitization, headed by building information modeling (BIM), has taken over as the preferred method for everything from design collaboration to scheduling, cost planning, and facility management, improving efficiency and quality along the whole chain (Miettinen and Paavola 2014). Digital tools are not reserved for designers and consultants at their desks, as on-site workers are also embracing the technology with access to the three-dimensional (3D) model on mobile devices. Along with this development, numerous associated mobile apps are made available for the construction phase, offering tools for anything from model viewing and safety monitoring (Azhar et al. 2015) to note taking, invoicing, and form filling – the latter going under the label of workflow apps.

Mobile apps specifically designed for construction defect management, commonly called snagging apps, are meant to simplify surveys, inspections, reporting, communication, and more, and thus improve the handover process. Instead of filling out and updating detailed paper forms describing the nature, location, responsible person, and status of each issue and taking steps to communicate this information to the right persons, snapshots are taken, the position is indicated (with the use of GPS) on a floor plan, and instructions are sent directly to the responsible people. The information is readily understood, and when action has been taken, feedback is immediately given and the issue is closed. All can be handled on smartphones or tablets (Bowden et al. 2006).

This represents a significant change in work procedures. As with all institutional change, it might happen that the transition is resisted (Oliver 1991). This might be because the new technology is perceived not to be useful or found to be difficult to use (Davis 1985). It is important for change to happen that the users experience relative advantage of new solutions over the familiar processes that they replace (Rogers 2010).

Wishing to answer the question “Will digital defect management systems be accepted by the parties involved on construction sites?”, we conducted a case study and interviews with project managers and on-site workers on various building projects in Norway, where the “* Capture” snagging app (RIB 2019) was deployed. The interview questions were guided by the technology acceptance model (TAM) (Davis 1985), our chosen theoretical approach. Thus, we hope to disclose any barriers to the employment of a relatively new technology that might improve the quality of buildings under construction.

An early version of this study has been presented at the Creative Construction Conference 2019, and the conference paper was published in the proceedings (Rolfsen et al. 2019). This is an extended version of that paper. Some of the text has been modified, and citations have been added. Furthermore, the respondents have been approached with follow-up questions regarding actual continued use of the technology.

This article starts with an introduction to the theoretical lens; next, the software and our research method are described. Findings are presented and analyzed according to the theoretical construct, and finally the discussion and conclusion answer the research questions.

2 Theoretical lens

Several theoretical models explaining adoption and acceptance of new technology exist (e.g. TAM, unified theory of acceptance and use of technology, actor network theory, and diffusion of innovations) (Merschbrock 2012). The TAM has informed research on the user acceptance of building management systems and research on individual beliefs about the outcomes of BIM use (Davies and Harty 2013; Lowry 2002). TAM can be viewed as an adaptation of the theory of reasoned action to the field of information systems (Venkatesh et al. 2003). The model depicted in Figure 1 builds on the original TAM model introduced by Davis (1989) and the theoretical extensions (e.g., TAM2) suggested by Venkatesh and Davis (2000). Diverging from the original TAM and TAM2 models, the construct names “intention to use” and “usage behavior” have been replaced with “behavioral intention to use” and “actual system use”, respectively. This has been done in accordance with what has been proposed by Venkatesh et al. (2003). TAM suggests that perceived usefulness and perceived ease of use will determine an individual’s intention to use and sees “behavioral intention to use” as a mediator of actual system use. A strong emphasis is placed on the user’s subjective opinion.

The main TAM constructs are (1) perceived usefulness – “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis et al. 1989), (2) perceived ease of use – “the degree to which a person believes that using a particular system would be free of effort” (Davis et al. 1989), (3) behavioral intention to use – users’ intention of use of the system in the future (Venkatesh et al. 2003), and (4) actual system use – users’ continued use of the system for performing work tasks (Venkatesh et al. 2003). TAM has proven its value for explaining how users come to accept and use new technology, making it a good fit for our study (Rolfsen and Merschbrock 2016).

There have been many attempts to extend the model by introducing new factors or disclosing moderators for perceived usefulness and perceived ease of use (Wixom and Todd 2005). In later developments of the theory, Venkatesh et al. introduced moderators such as gender, age, and experience (Venkatesh et al. 2003), some of which we also look at in this paper. A possible criticism of TAM might be that behavioral features play in, so that if someone has an intrinsic motivation to act (e.g., enjoyment) (Davis et al. 2006), he or she will be free to do so. This, however,

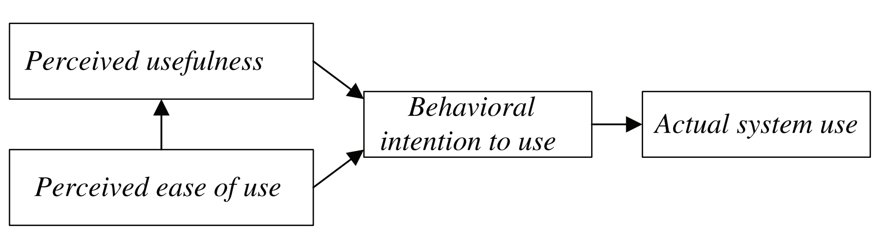

Fig. 1: Technology acceptance model (Davis 1985; Venkatesh et al. 2003; Davis 1989).

would not be the case in practical settings where, for instance, organizational rules or resources prevent people from acting freely (Merschbrock and Rolfsen 2016).

3 Method

A case study was considered appropriate since it allows for exploring "sticky practice based problems where the experience of the actors are important and the context of the action is critical" (Benbasat et al. 1987). The main case study was conducted by three students from Oslo Metropolitan University at an apartment building construction project in Oslo, Norway. The main contractor, Contractor 1, were using a combination of paper and a digital workflow management software for organizing their documents and forms. The workflow management software (called "the traditional method" in the following) had no link to BIM and no "snagging" function. The defect management application "* Capture" was presented to the team of Contractor 1. Next, two separate inspections were carried out with the app on the case site, with a project engineer and a site manager attending. Various functions of the app were explored: registering the project, 2D drawings and involved parties, registering nonconformities, snapping photos and marking their locations in the plans, and linking each issue to the appropriate subcontractor. The students participated in the inspections to get an impression of the users' benefits from using the program and of their practical understanding of the application itself. Interviews were conducted a couple of weeks after the demonstrations, when the users, including subcontractors, had had a chance to gain some experience with using the system. The data were collected through semi-structured interviews (face to face, Skype, and e-mail) with nine construction professionals working on various sites, as a way to access the interpretations of informants in the field. The interviews were conducted in October 2016, at a point in time when the design and construction had not been finalized. To supplement the research, professionals with three other contractors not involved in the case project were interviewed. Table 1 provides an overview of the interviews conducted. Interview guides were designed based on the TAM.

The follow-up questions regarding actual system use were presented to the managers in November 2019, by e-mail. Two of the project/site managers who had been involved were no longer employed at their firms, but new contacts were made and answers to our questions were obtained. Table 2 shows the overview of follow-up interviews.

4 Findings

The analysis follows the structure suggested by the TAM presented in Section 2. First, the contractors' perceived usefulness of * Capture for carrying out their work is recounted. Second, the perceived ease of use of the application in the context of on-site construction work is recounted. Third, the behavioral intention to continue using * Capture for construction works as an indicator for actual system use in other projects is presented. Finally,

Tab. 1: Interviews conducted

Affiliation	Interviewee	Interview technique and duration
Contractor 1 (case project)	Project engineer1	Face to face, 45 min
Contractor 1 (case project)	Site manager 1	Face to face, 45 min
Contractor 1 (case project)	Project manager 1	E-mail
Contractor 1 (case project)	Carpenter 1 and plumber 1	Group interview 40 min
Contractor 2	Site manager 2	Phone interview, 40 min
Contractor 3	Site manager 3	Skype/telephone, 40 min
Contractor 3	Trainee 3	Skype/webcam, 40 min
Contractor 4	Project manager 4	E-mail

Tab. 2: Follow-up interviews conducted

Affiliation	Interviewee	Interview technique and duration
Contractor 1 (case project)	Project engineer 1	E-mail, phone interview
Contractor 2	Business developer 2	E-mail, phone interview
Contractor 3	Site manager 3	E-mail
Contractor 4	Chief operating officer 4	E-mail

we disclose the firms' actual continued use of construction defect management systems.

4.1 Perceived usefulness

Throughout the interviews, several factors were found influential for construction professionals' perceptions of usefulness. The first candidates interviewed were site managers and a project engineer. They were convinced that a good flow of communication is important in order to keep a good flow of work. This was enabled through the application's dialogue center, as pointed out by a site manager: "If, for example, I write that 'you need to fix a skirting board', or window moulding, then he can answer immediately and say that 'that's not my job, it's the carpenter's'. Then I can just change the contractor and send the message again". He added other ways in which time can be saved: "It takes less than a minute to note a fault and take a photo and send it to the person concerned. They get it immediately". Furthermore, he went on to say that "They know what they have to fix, so we can leave the flat and they can go in and do the job, so that we don't have to go through the faults", indicating that the system enabled the subcontractor to accomplish the task without further instructions. (site manager 2).

Another site manager further elaborated on this, explaining how productivity and effectiveness on the site are increased: "I would say that our craftspersons and subcontractors have taken a positive view because they think it's good that they can go out on the site and don't have to spend time walking back and forth to look through lots of documents and binders. It's very convenient not having to deal with paperwork". Furthermore, effectivity in the office is enhanced: "It's useful because you don't have to use documents. That's the thing. You can sort things more easily. You get the whole overview [...] You can sort things by flat, discipline etc". (site manager 1).

Contractor 1 had previously used a general workflow app to register nonconformities. This method in many ways resembles the traditional method of operating with paper forms and physical files. When experiencing the functionalities of * Capture, the project engineer interviewed at the main case study commented:

> "The fact is I haven't used either the traditional method or * Capture before, so I was a clean slate. But after a couple of weeks of using the two different methods, it is clear that * Capture is the most useful option, it's easy to communicate with the different parties and take photos and have systematic documentation. It's simple compared to the traditional method. The principle is largely the same – you go on pre-inspections in the flats and look for faults that need to be remedied, but it's the process itself that is the real difference between the two programs. For me, * Capture is the winning product". (project engineer 1)

He was then asked the question: Would you define the model as being useful on the construction site? He answered:

> "Definitely. […] Having this documentation saved in an application makes it much easier to find than having lots of binders. If I were to compare these two programs, The traditional method and * Capture, I'd say that * Capture is a simpler means of accepting or rejecting points, since you can reject or accept on the site. With the traditional method, you have to go to the office, find the right binder and see if the subcontractors have actually remedied faults or not, and if no one lets you know, you never know if things have been done or not. With * Capture, I'm notified via email that something has been done, and I can go in and see who has remedied the fault, and, if I see, for example, that something isn't good enough after a quick control, I reject it. I do miss a better set-up in * Capture, having a field for descriptions where you have to write everything in a sentence instead of points. Also automatic notifications on the phone, so you don't have to go in to check whether things have been done". (project engineer 1)

It is of great interest to hear how the skilled workers perceived the new tool in terms of usefulness. After all, they are the ones doing the actual work on site. A brief group interview was therefore conducted with the carpenter foreman and plumber foreman in the main case study. They said the following: "In the past, we got emails with a list of faults and defects, and after we had gone through it, we went to the office to have it signed. In a way, the answer is that with * Capture, you don't have to make that trip to the office, and everything is in the same place" (carpenter 1). The plumber foreman had this to say:

> "In the past, I received a lot of different emails, and it was difficult to find the email you wanted. With * Capture it's easier, because all the emails you want to find are already there in * Capture. […] It's simpler to find things in the long term. Then I can go back and see Block A two months ago, for example". (plumber 1)

He continued: "If it hadn't been for the dialogue center, I would have phoned or written some questions on a piece of paper. […] It's quicker, easier to keep track of things" (plumber 1).

4.2 Perceived ease of use

After having tried the application for a few weeks on site, the users were asked how easy they perceived it to be.

On site, some were skeptical at first: “I was maybe a little skeptical of the application, but it went ok” (carpenter 1). However, in just a short time, the users found the application easy to use and that it simplified their work. This is supported by the following quote: “It’s very easy to use. As I said to the subcontractors on the construction site: ‘get to know the application, play around with it a bit’. And after a few hours they were up on it” (project engineer 1). “I find it very easy to use [...] If you can use a computer, you can use this” (site manager 2).

In general, new digital tools require training of users. Nearly all the respondents found this easy. “Training doesn’t take long. […]. If the subcontractors ask for help, we in the construction site management help them, but there haven’t been any particular difficulties” (trainee 3). On the other hand, proper training costs time and money. “Of course, if the training had been ... If we had provided more training, they would have used the functions more. This was a pilot project, so we didn’t know whether we would be continuing with * Capture or not. So we didn’t put all our efforts into teaching everyone everything 100%” (site manager 1).

It was found that age can be an obstacle to using digital tools on the construction site, even though the program is not very advanced. When asked whether there were any disadvantages, the following was commented: “Only the ‘pensioner’ would have problems with all the options out there. It took him a long time to learn the traditional method as well. In the past, he just went around with pen and paper. To me and Abdul who are quite up-to-speed on technology, it wouldn’t be difficult” (site manager 1). One project manager who had some experience said: “Those without sufficient smartphone competence struggle” (project manager 4), adding: “And there’s not much of that these days”. This indicates that age is a diminishing problem, as was supported by another: “* Capture is a modern tool in an age where mobile phones or tablets are used for most things” (site manager 1).

Language can also be an obstacle on the construction site. However, this particular obstacle was overcome by the use of the tool:

> “It’s quite easy to use, these are the kinds of problems that are typical in the construction industry, and communication is an issue with many foreign workers. For those who actually have a smartphone – not everyone has one – for those who have, it’s easy to use photos to show the position of the fault so you don’t have to write so much, which is often easier for people who can’t speak English or Norwegian to understand what you mean and where” (site manager 1).

4.3 Behavioral intention to use

The behavioral intention of using * Capture in future construction projects is evident, in spite of some initial skepticism: “Yes, we want to use it for the next block of flats as well. We want to learn more about the software so that we can carry out a good assessment of whether we want to continue using it. […]. If it’s profitable, then we’ll certainly give it a go” (project manager 1). His colleague was even more positive: “We like to be part of new trends, see new things and, not least, learn new technology. If it’s profitable, then we’ll certainly give it a go”. He also intended to encourage others to try it out:

> “Word is getting around here that we are using a program that works well, so we have informed the other projects. […] I would definitely recommend * Capture to others. I’ll be going down to a project close by shortly where we’ll be doing a really big project with 440 flats, and I will definitely mention it (* Capture) there”. (project engineer 1)

The site manager however saw some issues related to communication with external actors:

> “I would like to use * Capture on inspections with customers and in connection with handover, getting everything from the traditional method over to * Capture. But, as I said, the format needs changing or the way the points are displayed, into the protocol to be signed by the customer and things like that. Because when we do the round with the customer, the customer must receive the faults in a protocol by email, and the subcontractor must check the points or we must, while we must also have the possibility of checking them against the customer, so it’s a twofold process in a way”. (site manager 1)

4.4 Actual system use

Contractor 3 had already been using * Capture for several years and never looked back. In this respect, one could say that once the decision to go for the system had been taken, the way forward to fully adopt it was clear. “I’m pretty sure that Capture has been used in several projects and for many years now, at least in our company. During my career here, I’ve used Capture on two projects […]. As for the concluding projects, I don’t think they’ll use anything else”. Furthermore, they actively encourage their subcontractors to adopt the system too: “It was a bit challenging in the beginning to get everyone to use the system. But the more we use it, the more I think everyone will be properly informed that * Capture is the method used on the construction site” (site manager 3).

Three years after these interviews, the four firms were again contacted with the question “Are you still using * Capture?” Contractor 3 was clear in their response: “We are still using * Capture” (site manager 3). The answers of the other three firms, however, were all negative.

This prompted a set of follow-up questions: “Why not?”, “What are you using instead?”, and “What was the reason – usefulness, ease of use, or other?” It soon turned out that all three had landed on comparable mobile applications for defect registration and reporting. Contractors 1 and 2 had both landed on the same product. According to the Business Developer with Contractor 2, “The tool that is most used with us today is (a competitor). I don’t know of any projects which use * Capture. (The competitor) is probably often chosen because it has a functionality that suits our needs, checklists are easy to adapt, and some of our subcontractors are already using it”. Contractor 4 uses several different digital solutions – one BIM construction software, which includes a capture app for their general quality assurance, as well as other snagging apps at handovers. “The process is very client governed. We prefer not to mix operation and handover. It also has to do with cost benefit” (chief operating officer 4).

5 Discussion

The TAM served well as an analytical tool for explaining user choice of technology in the context of construction projects. Table 3 shows a brief summary of the main findings. The findings indicate that the defect management app tested was viewed as advantageous for various aspects of the building process.

The case study and the results of the interviews show that using IT systems leads to great benefits and significant time savings when dealing with faults and defects during preinspections and handover on construction sites. The interviewees’ views on using various software depend on whether the users see the usefulness and ease of digital tools. In the study, it was found that the users were willing to change their work methods, although they were skeptical at first.

In the group interview with the foremen of the carpenters and the plumbers in the case project, the interviewees explained that when they used the traditional method, they had to print out the forms for registration. Here, the way the registration was structured meant that the registrations collided between the different disciplines’ activities, which made it difficult for the skilled workers to get a clear overview of their own activities. The defect management app solved this problem, since registrations were sent directly to the appropriate recipient. When using the app to register faults and defects on the part of a subcontractor, this subcontractor received a simple message by email stating that a case has been opened. This was one of the positive aspects of the program that made the skilled workers prefer a defect management app over the traditional method. Good collaboration between all the parties involved is a prerequisite for using the technology. This also means having a good flow of communication so that certain problems can be prevented before growing more serious.

Several players in the construction industry are loyal to traditional methods. This is often because site managers and skilled workers prefer to do the job they are used to doing, and because they have a conservative way of thinking that can cause frustration in relation to new work

Tab. 3: Summary of results (right column) in relation to TAM items (Davis 1989) (left column)

Perceived usefulness – TAM	**Perceived usefulness – results**
Works more quickly	Does the job quicker
Job performance	Increases productivity and efficiency
Increases productivity and efficiency	Improves flow of communication
Makes job easier	Makes job easier
Perceived ease of use – TAM	**Perceived ease of use – results**
Easy to learn, clear, and understandable	Easy to learn
Easy to become skillful	Impact of experience/age difference
Easy to use	Easy to use
Behavioral intention to use – TAM	**Behavioral intention to use – results**
Results from perceived usefulness and ease of use	Results from perceived usefulness and ease of use
Actual system use – TAM	**Actual system use – results**
Results from intention to use	Use of a comparable system resulted from intention to use

TAM, technology acceptance model.

methods. For the case project, gender did not appear to affect the users' perceptions of usefulness and ease of use, but age and experience with information technologies (ITs) did. This was, however, only a minor problem, mainly because most of the employees were aged between 30 and 50 years and comfortable with using digital systems. The software does not require high IT competence and is easy to use for everyone in the industry. The people responsible for registering faults and defects felt that this was more systematic in the program, and the access to information meant that the parties could easily learn the system. The skilled workers gained interest in using the technology.

The fact that none of the contractors new to * Capture opted for the specific product may seem in contradiction to the theory. However, it is important to note that they all continued to use a mobile app for construction defect management, with the functionalities of snapping photos, registering position on plans (or in a 3D model), writing notes, sending directly to involved parties, filling forms, following up on completion, and filing. While there may be some variance in the sophistication of the software (active link to the BIM model, compatibility with other construction management systems), the interactive, mobile way of working is the same. The decision on which specific product to adopt was to a large degree taken by management and influenced by other factors such as cost, compatibility, and organizational policies. Being interactive systems, it is of great importance that all involved parties in a project use compatible software.

6 Conclusion

This paper has presented a case study of a construction project where a construction defect management app was used. By basing the study on core concepts of the TAM, it became possible to answer the research question: Will digital defect management systems be accepted by the parties involved on a construction site? Our findings illustrate that the application was perceived as a useful tool to efficiently improve and minimize faults and defects in the completion phase of a building project. It was found that all involved parties saw the app as user-friendly, since it was easy to use and quick to master. The perceptions of managers and skilled workers alike led to a willingness to take the technology into use. In the study, it was furthermore found that such a tool is likely to be adopted for continued use and thereby has a great potential for improving the end quality of construction projects.

Our study is limited in that it only involved one technology application and a handful of respondents. Nevertheless, the findings were mutually consistent and in accordance with the TAM. Further research might uncover which features are most useful and which might be made even more accessible, also for users with limited IT competencies.

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